The profit potential in reverse supply chain functions for catalyst manufacturers

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Summary abstract
The reverse supply chain (RSC) contains inherent uncertainties, e.g. the quality level and return volume of used products. By contrast, the catalyst manufacturing industry is characterized by certainty (manifested in e.g. well-defined and highly controlled production-processes and widespread standardization). This paper's purpose is to examine whether RSC-processes can be profitably applied in this industry. Using case study research the paper examines which RSC-functions that are generally available to manufacturers are profitable for a selected catalyst manufacturer. Results show three profitable RSC-functions. These results contribute to the emerging view of the RSC as a value creator rather than a costly nuisance.

Keywords: Reverse supply chain, reverse logistics, sustainable production, catalyst manufacturing, profitability, case study research

1. Introduction
While forward supply chains start with suppliers and end with customers, reverse supply chains (RSCs) begin *and* end with customers. In the prevalent RSC-concept by Guide and Van Wassenhove (2002), which Figure 1 illustrates, the RSC begins with acquiring used items from customers. These acquired items are then moved to a company facility, where they are first inspected and then sorted into recovery or waste streams. Items sorted for recovery are disassembled and recovered, and lastly the RSC either resells or reuses items internally. Literature often labels used items as *core* items.

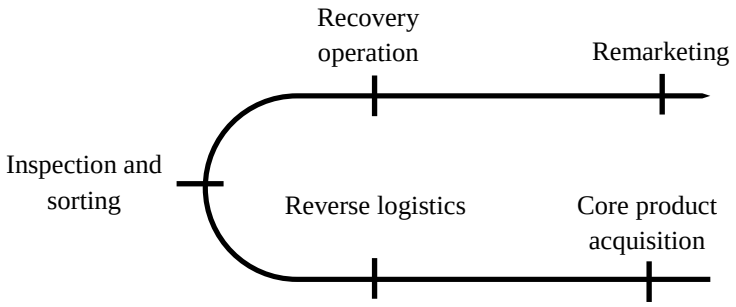

Figure 1- The reverse supply chain (Guide and Van Wassenhove, 2002)

Huscroft *et al.* (2013) conclude in a recent review of the RSC-literature that an important need for scholarly research is investigating how the RSC can be a profit-center in the organization. The Confederation of Danish Industry concurs with this research challenge by stating that one of the largest barriers for establishing RSCs in the organization is low (or no) profitability (Tronhus, 2010). Assessing the profit from the firm's RSC differs from other investments in the firm's operating system (e.g. automating a process or implementing a new layout) because the RSC has a wildly scattered set of financial effects across the whole business. The RSC is an integrated part of several functions across the firm's forward supply chain (e.g. purchasing, manufacturing, logistics, inventory, and sales) and has close to 25 different cost parameters (Larsen and Jacobsen, 2014). Furthermore, some of the RSC's benefits are often not included in business-case analyses. For example, recovery and resale may create direct profits when using a simple "revenue minus costs"-lens. However, such analyses fail to include the RSC-enabled effects on the wider business. For example, increasing service sales and increased probabilities of future virgin product sales (Larsen *et al.*, 2016a).

Also adding to the complexity is that although the RSC-concept depicted in Figure 1 appears rather straightforward, RSCs differ vastly. For example, one RSC may refurbish complete end-products for the purpose of resale, while another RSC may refurbish used components for the purpose of reuse in the firm's servicing of their installed base of products. Larsen and Jacobsen (2014) refer to these two examples not as RSCs, but as *RSC-functions*, because one RSC can contain several RSC-functions within the same set-up. Each of these RSC-functions contribute to the firm's profits. Which RSC-functions that have profit-potential differs between industries and the purpose of this paper is to explore the profit-potential for RSC-functions specifically in the catalyst manufacturing industry.

Catalyst manufacturers possess a set of characteristics that simultaneously indicate massive RSC profit-potential *and* high operational barriers. Catalysts contain valuable components and materials (including specialty metals) that have high potential for both reuse and recycling. However, the catalyst production process (that binds metals with chemicals) is standardized and highly controlled, and the industry has a "precision mentality". Both of these characteristics act counter to RSC-profitability given the inherent uncertainties in RSCs (e.g. product quality and return volume uncertainty). The potential and barriers for RSC-profit make this industry highly relevant to investigate from a practitioner perspective. From an academic perspective, examining the profitability of RSC-functions in this stability supports the emerging literature stream that views the RSC as a value creator rather than a costly nuisance for the firm, which has been the traditional view of the RSC.

The paper is structured as follows: Section 2 reviews literature and builds an analytical framework for examining the profit-potential in RSC-functions for catalyst manufacturers; section

3 presents the research design, which delineates how the study identifies profitable RSC-functions; section 4 presents findings; and section 5 and 6 discuss results and present conclusions.

2. Literature review

The purpose of this paper is to examine the profit-potential in RSC-functions for catalyst manufacturers. Therefore, the section first defines the RSC and what constitutes a RSC-function; second, the section reviews literature concerning profit-potential in RSC-functions; third, the sections develops a framework for evaluating the profit-potential in RSC-functions for a particular firm; fourth, the sections reports on academic operations management (OM) oriented papers dealing the catalyst manufacturing industry.

2.1 The RSC and the functions of the RSC

The traditional view of RSCs in both academia and practice is that of a nuisance or even "an unwanted stepchild of forward operations" (Mollenkopf and Closs, 2005), which has directed research on the issue towards cost reduction (e.g. Ilgin and Surendra, 2010). By contrast, a relatively new stream of academic literature, in which the RSC is an integrated part of a closed-loop supply chain (Guide and Van Wassenhove, 2009), views the RSC as "potentially profitable business propositions". This literature stream takes a business perspective when researching the RSC and its impact on the wider business.

The specific concept of the RSC that this paper applies is delineated and illustrated in the paper's first paragraph. The RSC can conduct a series of functions for the firm. The introduction names two examples. Formally, the paper defines a RSC-function using three constituent elements following Larsen and Jacobsen (2014): Item, Process, and Purpose. Geyer and Jackson (2004) name three potential items that the RSC can reprocess: Complete end-products, components, or materials. Theirry *et al.* (1995) name four potential processes that each define how the RSC can reprocess an item: repair, remanufacturing, refurbishing, salvaging components for direct reuse, and recycling materials. The first three apply complete end-products and components, while the last applies to materials only. Larsen and Jacobsen (2015a) present an example of a RSC with the following three RSC-functions (Figure 2 illustrates the RSC):

1. End-product refurbishing for resale as low-price versions of the OEM's original/virgin product to the firm's existing customers
2. Component refurbishing for reuse as spare-parts in the firm's post-sale service operations
3. Resale of core materials upstream to the firm's current virgin material suppliers (or to independent recyclers)

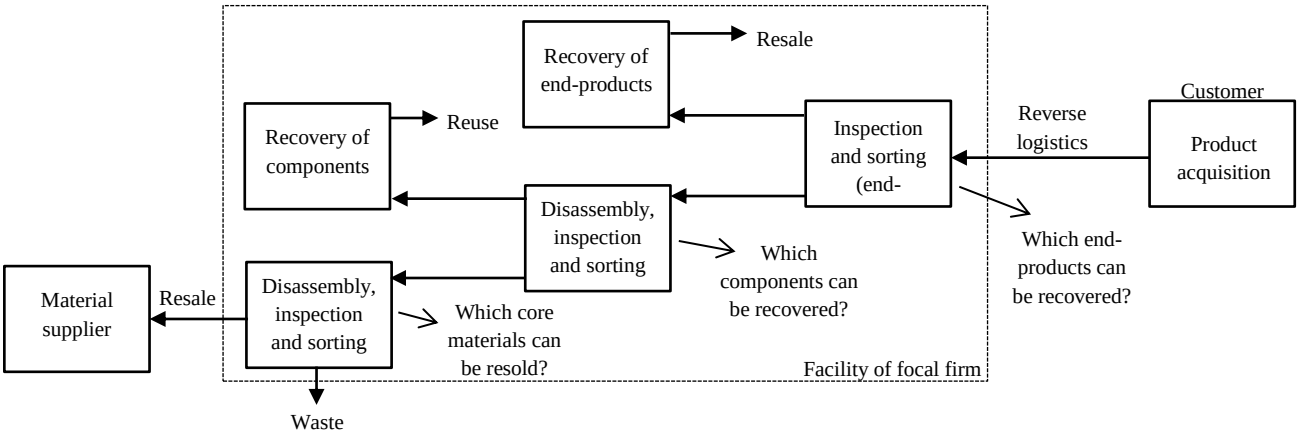

Figure 2 – A RSC with three RSC-functions (Larsen and Jacobsen, 2015)

2.2 How can RSC-functions provide the firm with profit

The three RSC-functions described in section 2.1 each provide the firm with either added revenue or reductions in operating costs of the firm's forward operations. RSC-functions no. 1 and 3 in the set provide the firm with added revenue from added sales of products to a segment of the market that may be impenetrable with the firm's higher-priced virgin products (RSC-function no. 1) and revenue from reselling core materials (RSC-function no. 3). RSC-function no. 2 provides the firm with reduced operating costs in the firm's forward operations by avoiding the costs of manufacturing virgin spare-parts. Larsen and Jacobsen (2015b and 2016b) present a set of RSC-enabled revenue streams and a set of RSC-enabled cost reductions in the firm's forward operations. Table 1 summarizes these two sets, which together make up 20 potentially profitable business opportunities, below:

Table 1 – Generally available RSC-options

RSC-enabled revenue streams	**A1**	Sales of disassembled core components to independent recovery firms (IRF)
	A2	Sales of core end-products to IRFs
	A3	Sales of core materials to independent recyclers
	A4	Sales of disassembled core components to original suppliers
	A5	Sales of core materials to original material suppliers
	B1	Sales of recovered components to primary market for virgin products
	B2	Sales of recovered end-products to primary market for virgin products
	B3	Sales of recovered components to secondary markets
	B4	Sales of recovered end-products to secondary markets
	B5	Sales of recovered components to direct competitors or related manufacturers
	C1	Added sales of virgin products through the addition of RSC enabled services
	C2	Added sales of virgin products through brand image refinement
RSC-enabled cost reductions in the firm's forward operations	**D1**	Replacing costs of virgin end-products through direct reuse of returned non-defect products
	D2	Replacing manufacturing of virgin end-products through recovery of used or defect products
	D3	Replacing manufactured virgin components through recovery of used or defect components
	D4	Replacing purchased virgin components through recovery of used or defect components
	D5	Reducing the cost of writing off returned non-defective products or components
	D6	Replacing purchase of virgin materials for in-house component fabrication
	D7	Reducing external cost of quality
	D8	Reducing landfilling costs through recycling

The firm can realize the benefits that Table 1 details using the RSC. However, the RSC's processes have costs. The profit that the RSC can provide the firm equals the net earnings from using one or more RSC-functions.

RSC-enabled profit = Value produced by the RSC – the costs of the RSC

Larsen and Jacobsen (2014) examined the cost parameters (cost types) that the RSC contains. These are dependent on the specific functions that the firm's RSC performs for the firm. The paper

examined cost parameters for a RSC with tree RSC-functions that are almost equal to the set presented in section 2.1. The paper identified 25 different cost parameters scattered across the whole business and include both costs of implementing and operating RSCs. Examples are costs of costs of buying back core items; costs of holding inventory of core and recovered items; costs of the processes of reverse transportation, cleaning, disassembling, and testing items; and costs of cannibalized virgin product sales. While the entire set of costs is impractical to show here, the set functions as an integral part of the case analysis, which is detailed later in the paper.

Larsen *et al.* (2015) summarize the RSC's benefits and costs one illustration:

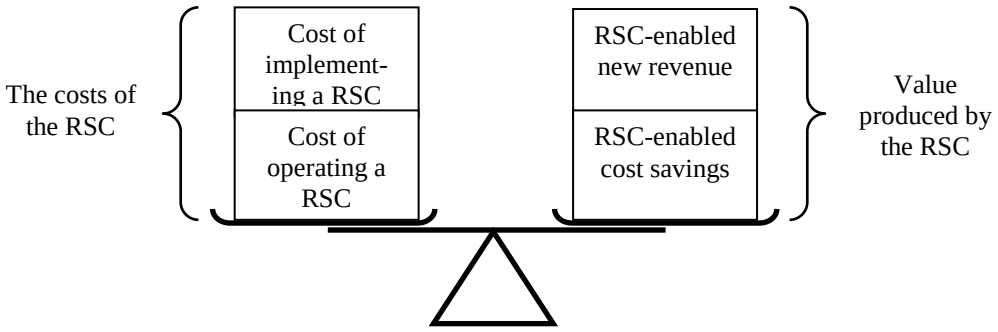

Figure 3 – The benefits and costs of the RSC

2.3 A processual framework for evaluating the profit-potential in RSC-functions

The processual framework has two basic steps: The first step filters the set of twenty theoretically available RSC-functions presented in Table 1 using knowledge about the case firm's markets, products and operating system as filter. A selected set of potentially profitable RSC-functions emerges. The second step evaluates the profitability of the selected RSC-functions.

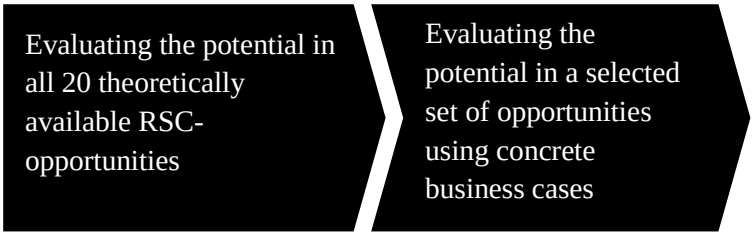

Figure 4 – Processual framework

2.4 Academic literature within the OM domain concerning the catalyst manufacturing industry

Catalyst manufacturing appears to be an unexplored industry from an OM perspective. Within academic OM-journals only one paper deals with the industry. The one article (Schmidtke *et al.*, 2014) uses a catalyst manufacturer as a case firm to examine how the integration of discrete event simulation can work in a value stream mapping project. The industry is not the object of investigation per se, which underlines how little attention the industry has received from OM or supply chain management researchers. Catalyst manufacturing is, however, well-researched from a technical viewpoint, e.g. in journals such as Topics in Catalysis and the International Journal of Mineral Processing. These journals deal with technical issues in recovery of specialty metals from spent catalysts (e.g. Angelidis, 2001, and Dong *et al.*, 2015). Results indicate an economical

potential inherent in recycling of materials, which indicate profitable opportunities in A4 and A5 in Table 1.

3. Research design

Given the under-developed state of the OM-literature that concerns RSCs in the catalyst manufacturing industry, the paper uses a case-based research design. Case studies allow for exploratory investigation of a focused phenomenon using rich contextual data from real-world settings (Barrat *et al.*, 2011). A catalyst manufacturer is selected as case firm. The case firm produces and sells catalysts globally, which reduces regional bias.

Two of the paper´s four authors worked part-time in the case firm and have conducted the case study in an embedded action-research style (see Figure 5). Traditionally, action research is applied for studying "an unfolding sequence of actions over time in a given group, community or organisation". These sequences of actions are usually studied live and researchers take active parts in the events as an actor (Coughlan and Couglan, 2002). During the spring of 2016 the two researchers, who conducted this analysis, worked in cooperation with case firm personnel using the processual framework delineated in the section 2.3 in the literature review. The two researchers had access to all relevant data and persons within the firm and made contact to relevant actors outside the firm, e.g. customers, recyclers, domestic and foreign embassies, and environmental protection agencies.

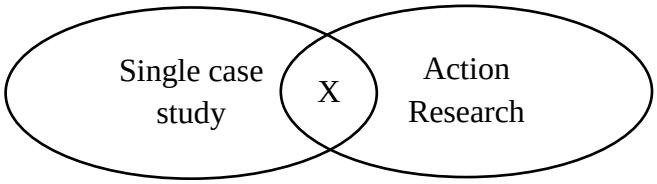

Figure 5 – Methodology

The first step in the study, which concerns filtering the set of 20 RSC options that are theoretically available, was conducted through a meeting between the study's two embedded authors and the case firm's three operating divisions. The divisions were represented by their general managers. During the meeting and in the weeks following the meeting the set of theoretically available RSC-functions was filtered. The result from the first step was a set of RSC-functions selected for further examination. These selected RSC-functions were first discussed in work-shops with staff from the firm's sales, legal, and supply chain departments. In addition, a member of the firm's tax department participates to ensure correct inclusion of taxes, duties and other fees involved in global transport of used products and waste. Second, in daily cooperation with the case firm's staff the two embedded authors defined the specific flows of the selected RSC-function and the internal and external actors having roles in the flow. Furthermore, the embedded authors dealt with technical difficulties of the RSC-functions and conducted financial cost-benefit evaluations.

4. Case study findings

First, the section describes the nature of catalysts, how these are produced and delivered to customers, and finally how they are used and discarded by their customers. Second, the sections reports which RSC-functions are profitable.

4.1 Description of the case firm's forward supply chain, products and market

Customers can use catalysts for a number of purposes including filtering gasses and enhancing chemical processes. The case firm produces catalysts for 25 different industries including petrochemicals, automotive, bio-fuels, and steel. The firm produces its products, which are developed in-house, in two factories in Northern Europe and the USA. Catalysts are produced from metals, which go through a number of chemical processes. Catalysts are delivered from the two factories to customers globally. The firm is in continuous contact with its customers (the users of the catalysts).

The case firm's production processes are standardized and highly controlled. Precision in the production ensures the highest degree of functionality of the end-product. The level of standardization and control has fostered a "precision mentality" as a core element of the firm's culture. This "precision mentality" support production of top quality virgin catalysts, but acts as a barrier to the implementation of reverse processes that entail substantial amounts om "imprecision" (e.g. an unknown reverse flow of core catalysts with varying levels of quality and documentation). Another barrier is national as well as international waste management regulations: The case firm manufactures and sells products, but is not (currently) certified for handling waste. Core catalysts are classified as waste, which creates barriers for reverse transportation across national borders as well as for conducting the actual recovery process, which requires a waste handling certificate.

4.2 The profitable RSC-functions

In spite of the barriers detailed in the prior section Table 2 shows the result of the study, which includes several profitable RSC-functions:

Table 2 - Findings

		Profitable	Worth consi-dering	Not worth consi-dering
RSC-enabled revenue oppor-tunities	**A1**			**X**
	A2		**X**	
	A3		**X**	
	A4			**X**
	A5		**X**	
	B1			**X**
	B2	**X**		
	B3			**X**
	B4			**X**
	B5			**X**
	C1	**X**		
	C2		**X**	
RSC-enabled cost reductions in the firm's forward operations	**D1**			**X**
	D2		**X**	
	D3			**X**
	D4			**X**
	D5		**X**	
	D6		**X**	
	D7			**X**
	D8		**X**	
Other	**E1**	**X**		

The case-study shows three profitable RSC-functions for the case firm (marked with an X in the "Profitable"-column). The first profitable RSC-function (B2) takes back and recovers complete end-products for resale. These recovered products are either 1) sold back to the original customer or 2) sold to the segment of price-sensitive customers not willing to pay full price for virgin catalysts. When items are destined for recovery and reuse, the items are not considered waste, which allows for international reverse transport. However, the recovery process itself cannot be handled internally for lack of a waste handling certificate. This process is outsourced to a competitor, who has a certificate and is willing to perform the process for the case firm.

The second profitable RSC-function (C1) adds the service "take-back of end-of-life products" to the total product offering. This service provides the firm with access to a market, which for legal reasons is impenetrable without offering this RSC-enabled service. Market access gives the firm added virgin product sales. Future profits from this market (from which the RSC-costs are subtracted) are therefore attributable to the firm's RSC.

The third profitable RSC-function (E1) is not part of the original theoretical framework. Instead, the function extends the framework to include direct sale of RSC-services to customers as a separate category (category E). The particular RSC-function that the case firm can sell is take-back of core catalysts. In typical catalyst user industries firms are responsible for managing the end-of-life of their products and production equipment. By using the RSC-enabled service, customers handle this responsibility. The service resembles RSC-function C1, but the service does not entail added virgin product sales and the service is not limited to the particular market addressed under RSC-function C1. As is the case with RSC-function C1, RSC-function E1 requires a non-waste-classification of core catalysts. This is reached by transporting core catalysts to an external recycler, who extract materials from the catalysts. The firm's net earnings from selling the service are positive.

5. Discussion

The results give a clear indication that the RSC can provide the firm with profit, even in highly standardized and controlled manufacturing environments. These findings contribute to the RSC business perspective literature stream and the literature about the closed-loop supply chain.

The literature about catalyst manufacturing published in technical journals (e.g. energy and materials) considers reuse of materials as a potentially profitable business proposition. This study did not find these RSC-functions profitable in the case study, but do find that materials recycling would be profitable if the world market prices for e.g. vanadium were higher or if governments would omit charging taxes for the excessive amounts of water necessary in the recycling process.

The RSC can deliver value to the firm a way that is not captured explicitly by the theoretical framework presented in the literature review: Direct sales of the RSC's services. Selling services creates new revenue for the firm, which is profitable to the case firm of this study.

6. Conclusions

While catalyst manufacturing is well-researched from a chemistry and energy perspective, the industry is nearly unexplored from an OM-perspective. This paper finds that the RSC can provide catalyst manufacturers with profits in three distinct ways. By demonstrating the profit-potential in RSCs within an industry focused on certainty (e.g. standardization and control), the paper contributes to the literature stream that views the RSC as a value creator rather than a necessary evil (e.g. Guide and Van Wassenhove, 2006).

The generalizability of findings is limited by a single case-study. However, given the state of the related literature, exploratory studies are an appropriate method that contributes to future theory-building.

In addition to the study's specific findings, the paper shows the application of a business-case method built on novel research on the RSC's value creation opportunities. This method can be applied with all manufacturers to locate profits from reuse and product recovery.

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